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Dear Sirs

PCT International Application No.: PCT/SG2004/000210
Title: AN APPARATUS AND METHOD FOR GENERATING
UNIFORM PLASMAS
Applicant: NANYANG TECHNOLOGICAL UNIVERSITY

We refer to the Written Opinion of the International Preliminary Examining Authority with a mailing date of 1 July 2005.

We enclose amended claims on pages 16-19. We also enclose a marked up copy of the amendments for the examiner's convenience.

The examiner considers claim 1 to be not novel and inventive over the prior art because the phrase "current sheet" is construed in a broad meaning to include an array of wires, cables, conductors, antenna rods, electrodes, or as a metallic plates, or so. The examiner also acknowledges that there exist differences between electrodes and antennas.

Claim 1 has now been amended to a method for generating a uniform plasma including an RF antenna having first and second unidirectional oscillating currents wherein the currents are oscillating at a frequency range of 300 to 1000 KHz. This is the feature of previous claim 8. We note the examiner indicated that claim 8 was both novel and inventive.

There is nothing in the cited prior art documents, D1 and D2, to suggest an RF antenna according to new claim 1. Therefore, we submit that claim 1 is novel and inventive over D1 and D2. Accordingly, we also submit that dependent claims 2 to 4 are also novel and inventive.

Claims 6, 9, 12 and 15 have now been amended to include the features of claims 8, 11, 14 and 17 which the examiner considers to be novel and inventive over D1 and D2. Accordingly, we submit that newly amended claims 5, 7, 9 and 11 and their dependent claims are novel and inventive over D1 and D2.

Claim 15 has been amended to recite a plasma reactor including an RF antenna arrangement wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 KHz. This feature is not disclosed nor suggested in D1 and D2. Accordingly, we submit that claim 15 and its dependent claims 16-18 are novel and inventive over the cited prior art documents.

Therefore, in light of the above, we submit that the claimed invention is novel and inventive over the teachings of the prior art documents.

Accordingly, we look forward to the issuance of a clear report.

Yours faithfully,



Keith Callinan
Patent Attorney
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End.

Claims

1. A method for generating a uniform plasma, the method comprising the steps:
 - a. introducing a process gas into a plasma reactor;
 - b. introducing an RF antenna having a first unidirectional oscillating RF current sheet in a first direction and a second unidirectional oscillating RF current sheet in a second direction inside the plasma reactor; and
 - c. wherein the first unidirectional oscillating RF current sheet is substantially perpendicular to the second unidirectional oscillating current sheet.
wherein the unidirectional oscillating RF currents are oscillating at a frequency range of 300 to 1000 kHz.
2. The method in accordance with claim 1, further wherein the RF antenna having first and second unidirectional oscillating RF currents sheets generate a time varying RF electrical field azimuthally shifted on 45° with respect to the first and second direction of the first and second unidirectional oscillating RF currents-sheets.
3. The method in accordance with claim 1, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.
4. ~~The method in accordance with claim 1, wherein the first and second unidirectional oscillating RF current sheets are oscillating at a frequency range of 300 to 1000 kHz.~~
54. The method in accordance with claim 1, wherein the first and second unidirectional oscillating RF currents sheets exhibit substantially no phase differences.
65. A method for generating a uniform plasma, the method comprising the steps:
 - a. introducing a process gas into a plasma reactor;
 - b. introducing a unidirectional oscillating RF current into a first plurality of current carrying conductors in a first direction and a second plurality of current carrying conductors in a second direction; and
 - c. generating a time varying RF electrical field azimuthally shifted with respect to the first and second direction of the unidirectional oscillating RF currents; and

d. wherein the unidirectional oscillating RF current in the first and second plurality of current carrying conductors exhibit substantially no phase differences; wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

76. The method in accordance with claim 65, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.

8. ~~The method in accordance with claim 6, wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.~~

97. A method for generating a uniform plasma, the method comprising the steps:

- a. introducing a process gas into a plasma reactor;
- b. introducing a first unidirectional oscillating RF current into a first plurality of current carrying conductors in a first direction;
- c. introducing a second unidirectional oscillating RF current into a second plurality of current carrying conductors in a second direction; and
- d. generating a time varying RF electrical field azimuthally shifted with respect to the first and second direction of the first and second unidirectional oscillating RF currents; and
- e. wherein the first and second unidirectional oscillating RF currents exhibit substantially no phase differences; wherein the first and second unidirectional oscillating RF currents are oscillating at a frequency range of 300 to 1000 kHz.

108. The method in accordance with claim 97, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.

11. ~~The method in accordance with claim 9, wherein the first and second unidirectional oscillating RF currents are oscillating at a frequency range of 300 to 1000 kHz.~~

129. A method for generating a uniform plasma, the method comprising the steps:

- a. introducing a process gas into a plasma reactor;

- b. introducing a unidirectional oscillating RF current into a first plurality of current carrying conductors in a first direction;
- c. introducing the unidirectional oscillating RF current into a second plurality of current carrying conductors in a second direction; and
- d. generating a time varying RF electrical field azimuthally shifted with respect to the first and second direction of the unidirectional oscillating RF currents; and
- e. wherein the unidirectional oscillating RF current in the first and second plurality of current carrying conductors exhibit substantially no phase differences;
wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

4310. The method in accordance with claim 4292, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.

44. ~~The method in accordance with claim 12, wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.~~

4511. An antenna arrangement for an inductively coupled plasma reactor comprising:
a first plurality of substantially parallel current carrying conductors oriented in a first direction;

a second plurality of substantially parallel current carrying conductors oriented in a second direction;

wherein the first and second current carrying conductors for carrying unidirectional oscillating RF currents in a first and second direction respectively; and

the first direction being substantially perpendicular to the second direction;

further wherein the first plurality of substantially parallel current carrying conductors is disposed planarly above the second plurality of substantially parallel current carrying conductors; and

wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

4612. The antenna arrangement in accordance with claim 4511, wherein the first and second plurality of substantially parallel current carrying conductors adapted to generate a time varying RF electrical field azimuthally shifted on 45° with respect to the first and second direction.

17. The antenna arrangement in accordance with claim 15, wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

18₁₃. The antenna arrangement in accordance with claim 15₁₁, wherein the first plurality of substantially parallel current carrying conductors are alternately electrically coupled to the second plurality of substantially parallel current carrying conductors.

19₁₄. The antenna arrangement in accordance with claim 18₁₃, wherein at least one capacitor is connected between a predetermined number of the first plurality of substantially parallel current carrying conductors and a predetermined number of the second plurality of substantially parallel current carrying for minimizing reactance.

20₁₅. A plasma reactor comprising:

- a. a plasma reactor chamber adapted for plasma processing and for introducing of a process gas; and
- b. an RF antenna arrangement comprising a first plurality of substantially parallel current carrying conductors in a first direction; and
- c. a second plurality of substantially parallel current carrying conductors in a second direction;
- d. wherein the first and second plurality of current carrying conductors for carrying unidirectional oscillating RF currents in a first and second direction respectively; and the first direction being substantially perpendicular to the second direction; and
- e. further wherein the first plurality of substantially parallel current carrying conductors is disposed planarly above the second plurality of substantially parallel current carrying conductors;

wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

21₁₆. The inductively coupled plasma reactor in accordance with claim 20₁₅, wherein the first and second plurality of substantially parallel current carrying conductors are disposed inside the plasma reactor chamber.

| 2217. The inductively coupled plasma reactor in accordance with claim 2015, wherein each of
the first and second plurality of substantially parallel current carrying conductors is contained
inside each of a plurality of dielectric sleeves.

| 2318. The inductively coupled plasma reactor in accordance with claim 2217, wherein the
plasma reactor chamber is adapted to accommodate the plurality of dielectric sleeves and still
maintain vacuum integrity of the plasma reactor chamber.

Claims

1. A method for generating a uniform plasma, the method comprising the steps:
 - a. introducing a process gas into a plasma reactor;
 - b. introducing an RF antenna having a first unidirectional oscillating current in a first direction and a second unidirectional oscillating current in a second direction inside the plasma reactor; and
 - c. the first unidirectional oscillating RF current sheet is substantially perpendicular to the second unidirectional oscillating current sheet
wherein the unidirectional oscillating RF currents are oscillating at a frequency range of 300 to 1000 kHz.
2. The method in accordance with claim 1, further wherein the RF antenna having first and second unidirectional oscillating currents generate a time varying RF electrical field azimuthally shifted on 45° with respect to the first and second direction of the first and second unidirectional oscillating RF currents.
3. The method in accordance with claim 1, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.
4. The method in accordance with claim 1, wherein the first and second unidirectional oscillating RF currents exhibit substantially no phase differences.
5. A method for generating a uniform plasma, the method comprising the steps:
 - a. introducing a process gas into a plasma reactor;
 - b. introducing a unidirectional oscillating RF current into a first plurality of current carrying conductors in a first direction and a second plurality of current carrying conductors in a second direction;
 - c. generating a time varying RF electrical field azimuthally shifted with respect to the first and second direction of the unidirectional oscillating RF currents; and
 - d. the unidirectional oscillating RF current in the first and second plurality of current carrying conductors exhibit substantially no phase differences;

wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

6. The method in accordance with claim 5, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.
7. A method for generating a uniform plasma, the method comprising the steps:
 - a. introducing a process gas into a plasma reactor;
 - b. introducing a first unidirectional oscillating RF current into a first plurality of current carrying conductors in a first direction;
 - c. introducing a second unidirectional oscillating RF current into a second plurality of current carrying conductors in a second direction;
 - d. generating a time varying RF electrical field azimuthally shifted with respect to the first and second direction of the first and second unidirectional oscillating RF currents; and
 - e. the first and second unidirectional oscillating RF currents exhibit substantially no phase differences;wherein the first and second unidirectional oscillating RF currents are oscillating at a frequency range of 300 to 1000 kHz.
8. The method in accordance with claim 7, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.
9. A method for generating a uniform plasma, the method comprising the steps:
 - a. introducing a process gas into a plasma reactor;
 - b. introducing a unidirectional oscillating RF current into a first plurality of current carrying conductors in a first direction;
 - c. introducing the unidirectional oscillating RF current into a second plurality of current carrying conductors in a second direction;
 - d. generating a time varying RF electrical field azimuthally shifted with respect to the first and second direction of the unidirectional oscillating RF currents; and
 - e. the unidirectional oscillating RF current in the first and second plurality of current carrying conductors exhibit substantially no phase differences;

wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

10. The method in accordance with claim 92, wherein the process gas comprises: argon, nitrogen, methane, or hydrogen or a combination of any of the mentioned gases.

11. An antenna arrangement for an inductively coupled plasma reactor comprising:
a first plurality of substantially parallel current carrying conductors oriented in a first direction;
a second plurality of substantially parallel current carrying conductors oriented in a second direction;
the first and second current carrying conductors for carrying unidirectional oscillating RF currents in a first and second direction respectively;
the first direction being substantially perpendicular to the second direction;
the first plurality of substantially parallel current carrying conductors is disposed planarly above the second plurality of substantially parallel current carrying conductors; and
wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

12. The antenna arrangement in accordance with claim 11, wherein the first and second plurality of substantially parallel current carrying conductors adapted to generate a time varying RF electrical field azimuthally shifted on 45° with respect to the first and second direction.

13. The antenna arrangement in accordance with claim 11, wherein the first plurality of substantially parallel current carrying conductors are alternately electrically coupled to the second plurality of substantially parallel current carrying conductors.

14. The antenna arrangement in accordance with claim 13, wherein at least one capacitor is connected between a predetermined number of the first plurality of substantially parallel current carrying conductors and a predetermined number of the second plurality of substantially parallel current carrying for minimizing reactance.

15. A plasma reactor comprising:

- a. a plasma reactor chamber adapted for plasma processing and for introducing of a process gas; and
- b. an RF antenna arrangement comprising a first plurality of substantially parallel current carrying conductors in a first direction;
- c. a second plurality of substantially parallel current carrying conductors in a second direction;
- d. the first and second plurality of current carrying conductors for carrying unidirectional oscillating RF currents in a first and second direction respectively; and the first direction being substantially perpendicular to the second direction; and
- e. the first plurality of substantially parallel current carrying conductors is disposed planarly above the second plurality of substantially parallel current carrying conductors; wherein the unidirectional oscillating RF current is oscillating at a frequency range of 300 to 1000 kHz.

16. The inductively coupled plasma reactor in accordance with claim 15, wherein the first and second plurality of substantially parallel current carrying conductors are disposed inside the plasma reactor chamber.

17. The inductively coupled plasma reactor in accordance with claim 15, wherein each of the first and second plurality of substantially parallel current carrying conductors is contained inside each of a plurality of dielectric sleeves.

18. The inductively coupled plasma reactor in accordance with claim 17, wherein the plasma reactor chamber is adapted to accommodate the plurality of dielectric sleeves and still maintain vacuum integrity of the plasma reactor chamber.